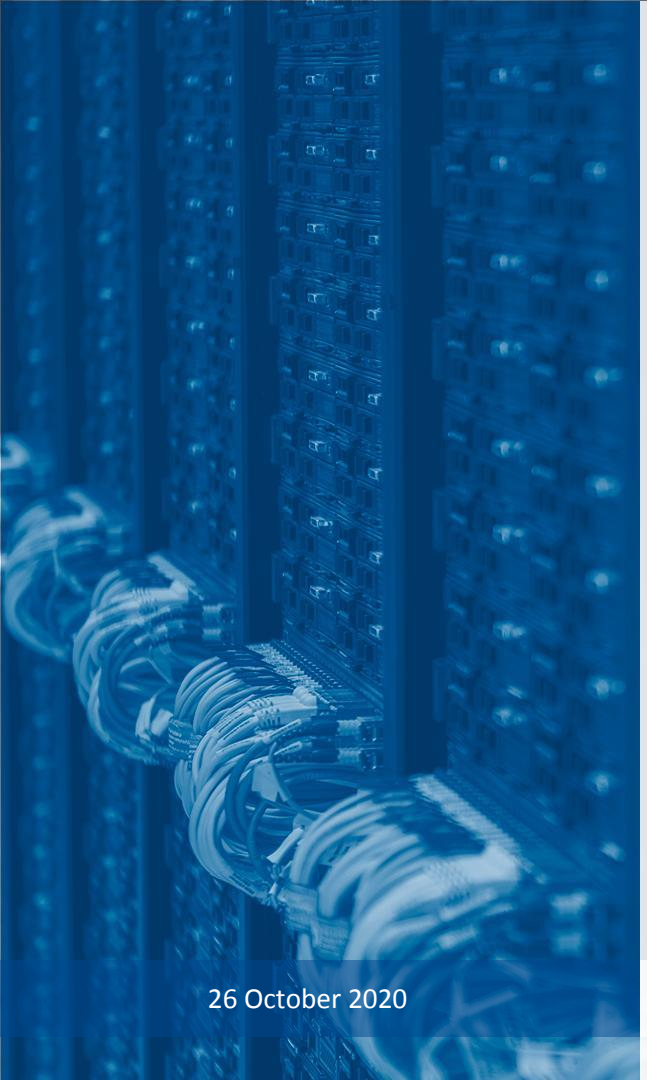

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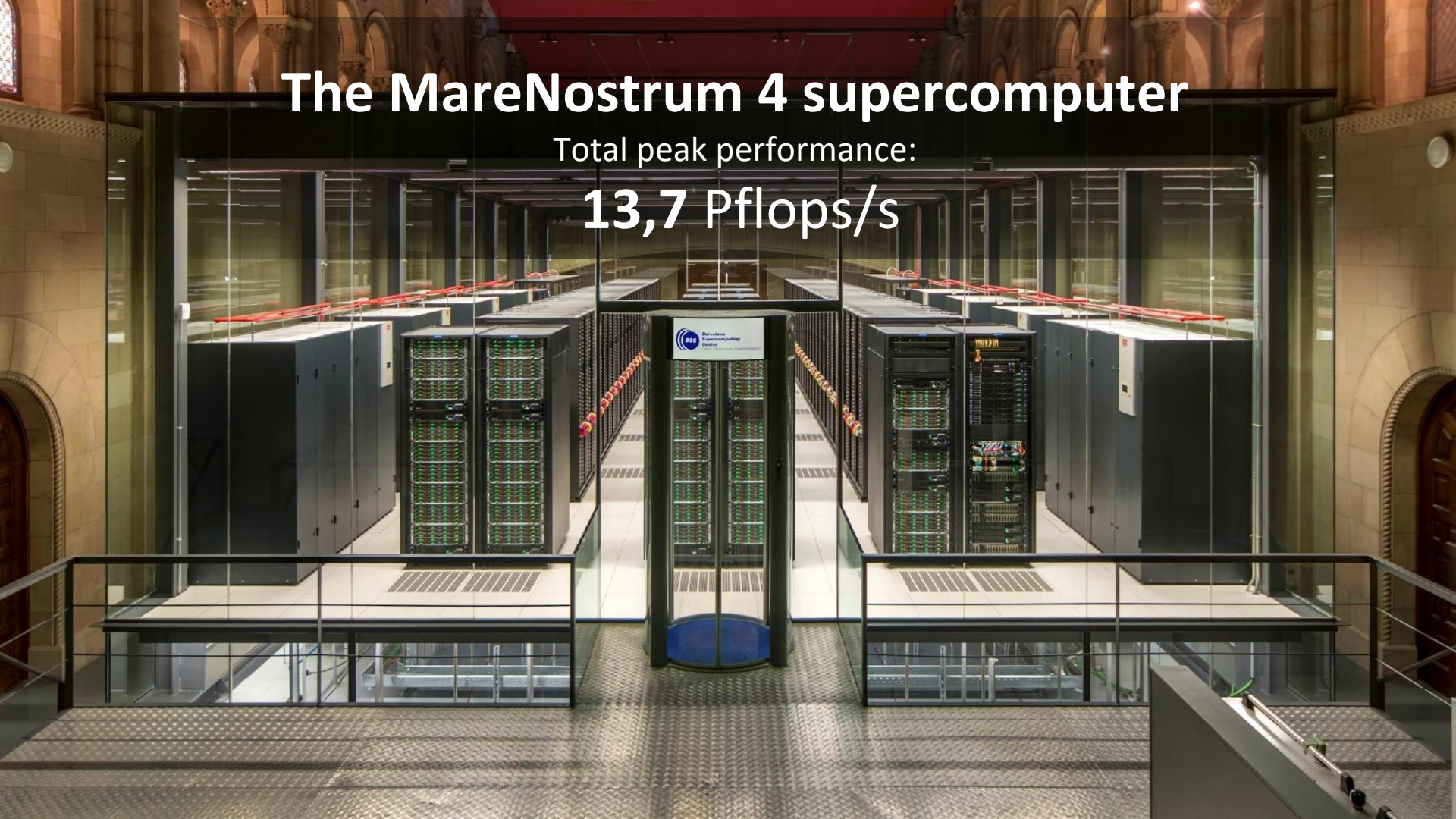
S2S4E
Climate Services for Clean Energy

# Sub-seasonal and Seasonal predictions for energy: breaking the barrier of chaos in the atmosphere

Llorenç Lledó, Albert Soret
& Francisco Doblas-Reyes
Earth Sciences department

26 October 2020

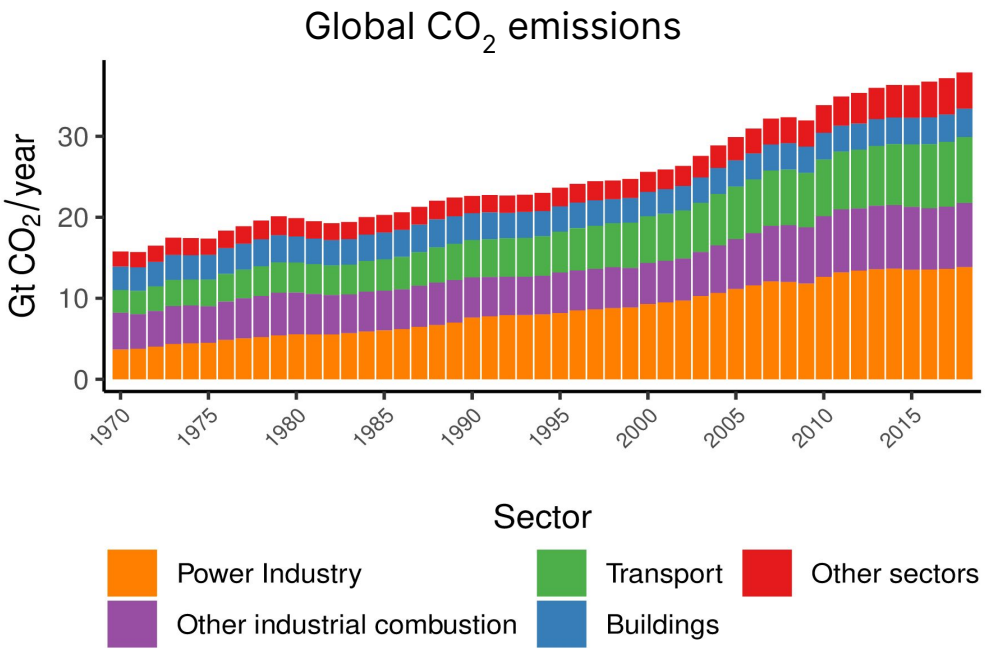
40th International Symposium on Forecasting


The MareNostrum 4 supercomputer
Total peak performance:
13,7 Pflops/s

# Outline

- Why extended range forecasts?
- How to break the atmospheric chaos barrier
- Using teleconnection indices to enhance sub-seasonal and seasonal predictions

# The energy sector is the largest contributor to CO2 emissions




Source: EDGAR

# Atmospheric variability impacts electricity generation & demand

## Wind power

Near-surface winds

## Solar power

Cloudiness

Humidity & aerosols

## Hydropower

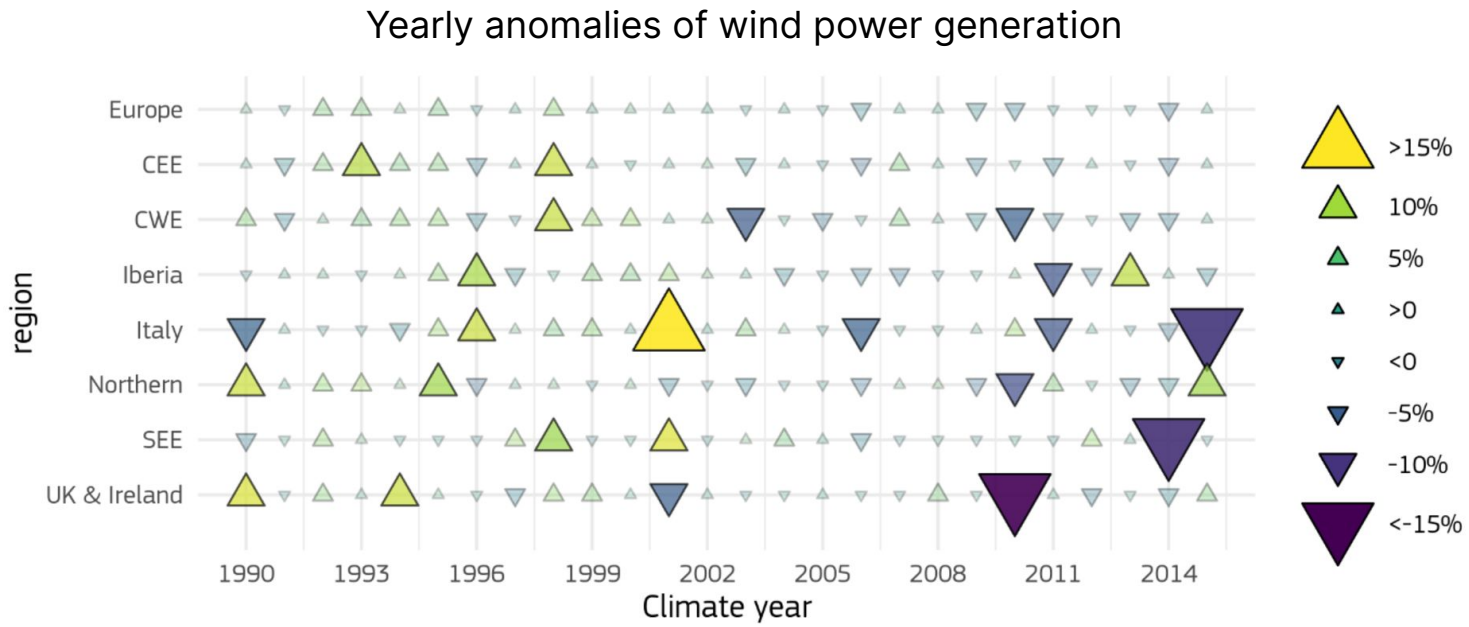
Precipitation

Snow melt

## Electricity demand

Temperature

# With higher shares of renewables in the mix, the electricity system is more exposed to atmospheric variability risks

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Source: De Felice et al. (2020)

# Can we anticipate weekly, monthly and seasonal anomalies of wind speed and wind power generation?

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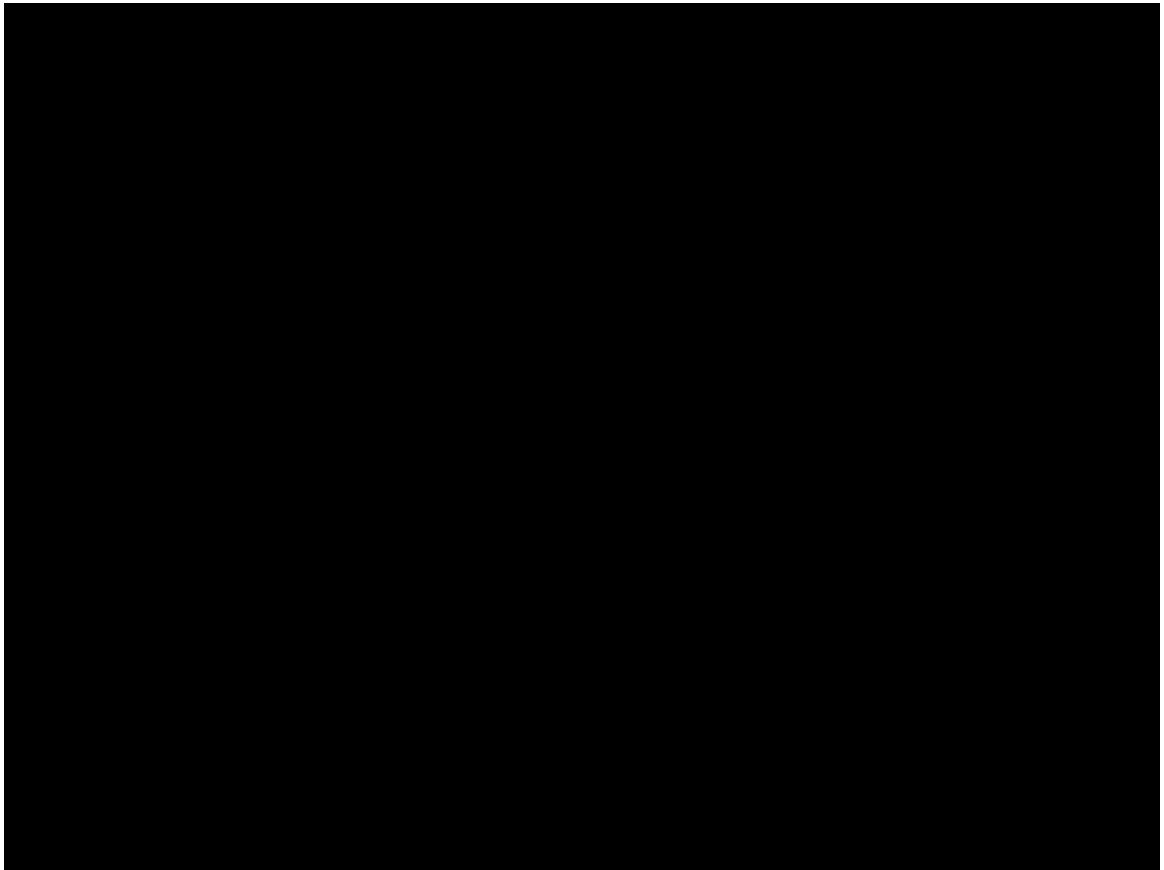
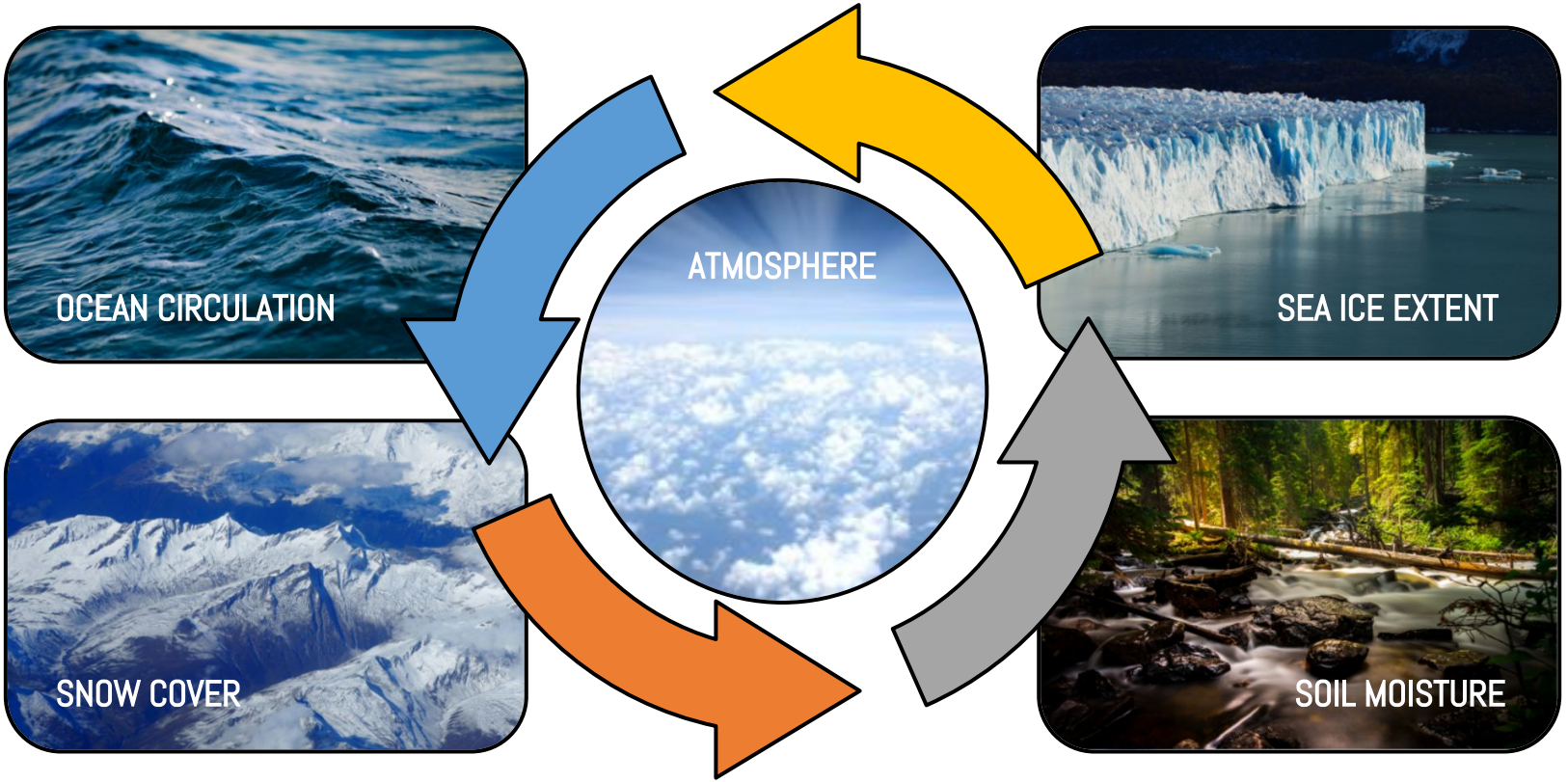
# The atmosphere has a chaotic behaviour

## Chaos

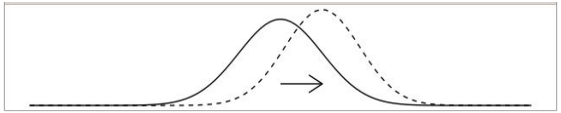
slightly different initial conditions lead to totally different trajectories



# The atmosphere interacts with other slowly-evolving components of the Earth System

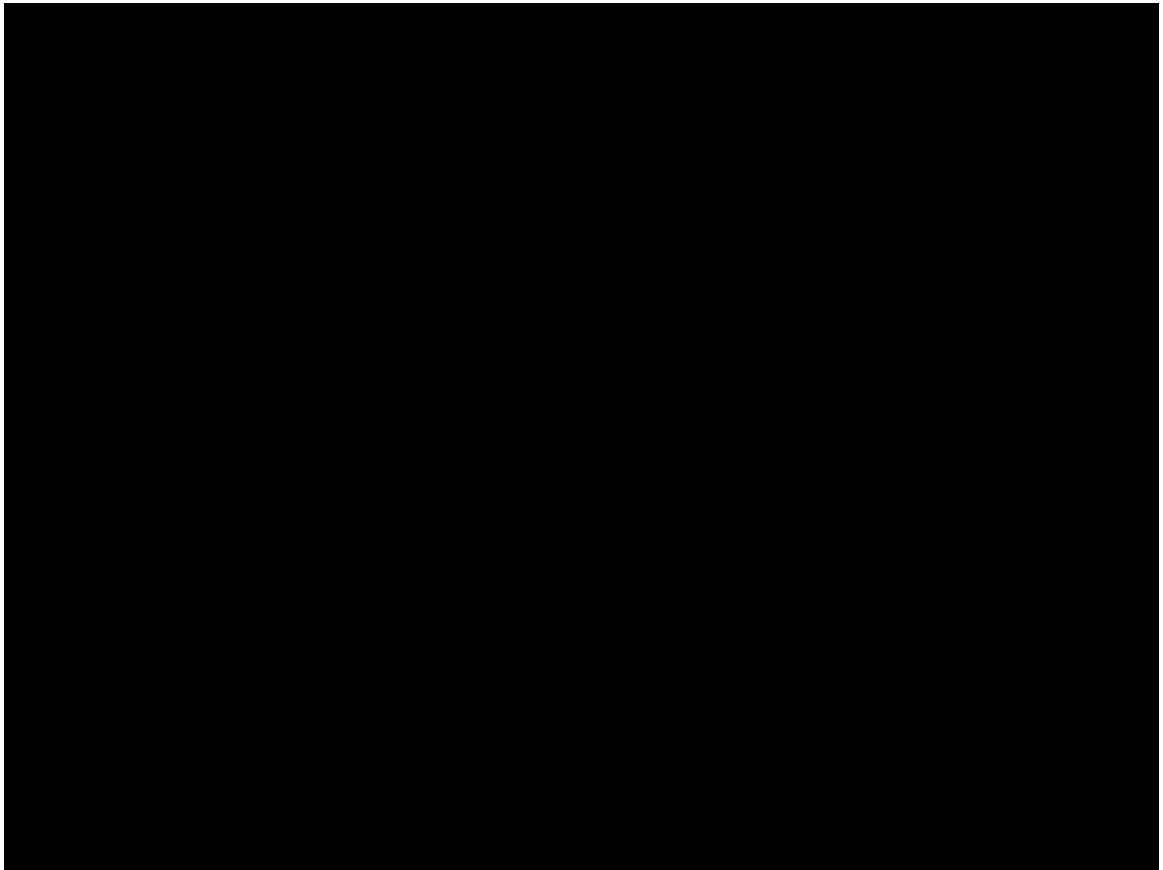


# Under an external forcing all the trajectories are modified



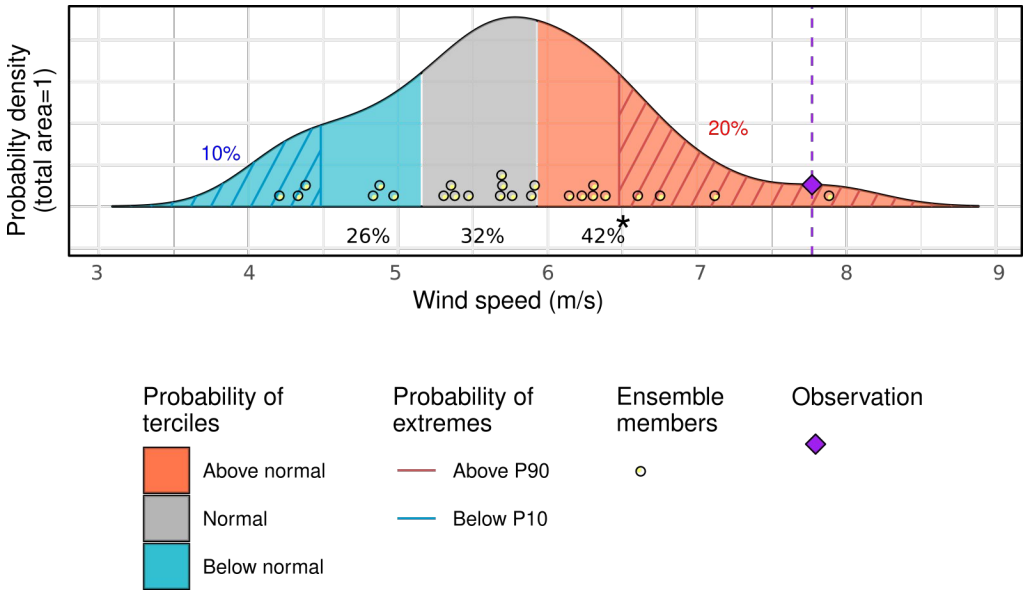
External forcing

a soft horizontal force



# A climate forcing can be detected in an ensemble of numerical simulations

- **Coupled Earth System Model**
  Forecast fast & slow evolution fields and its interactions
- **Ensemble members**
  Each member represents one possible system evolution
- **Signal extraction**
  Average whole period to filter noise and obtain forcing signal
- **Probabilities**
  Count members above/below threshold






Generated with CSTools R package

# Hybrid forecasts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# Hybrid forecasts / Perfect prog / Bridging

## Teleconnection indices

variables that describe physical process
or oscillations of the Earth system
(ENSO, NAO, MJO, QBO, PDO, AMV… )

**Observed TC impact**
$Impact \approx f(TC)$

+

**TC forecast**
$\widehat{TC}$

→

**Impact forecast**
$\widehat{Impact} \approx f(\widehat{TC})$

## Hybrid forecasts combine:

- a dynamical forecast of a teleconnection index
- a statistical model that relates observed impacts to TC index

# Sub-seasonal fcsts derived from MJO

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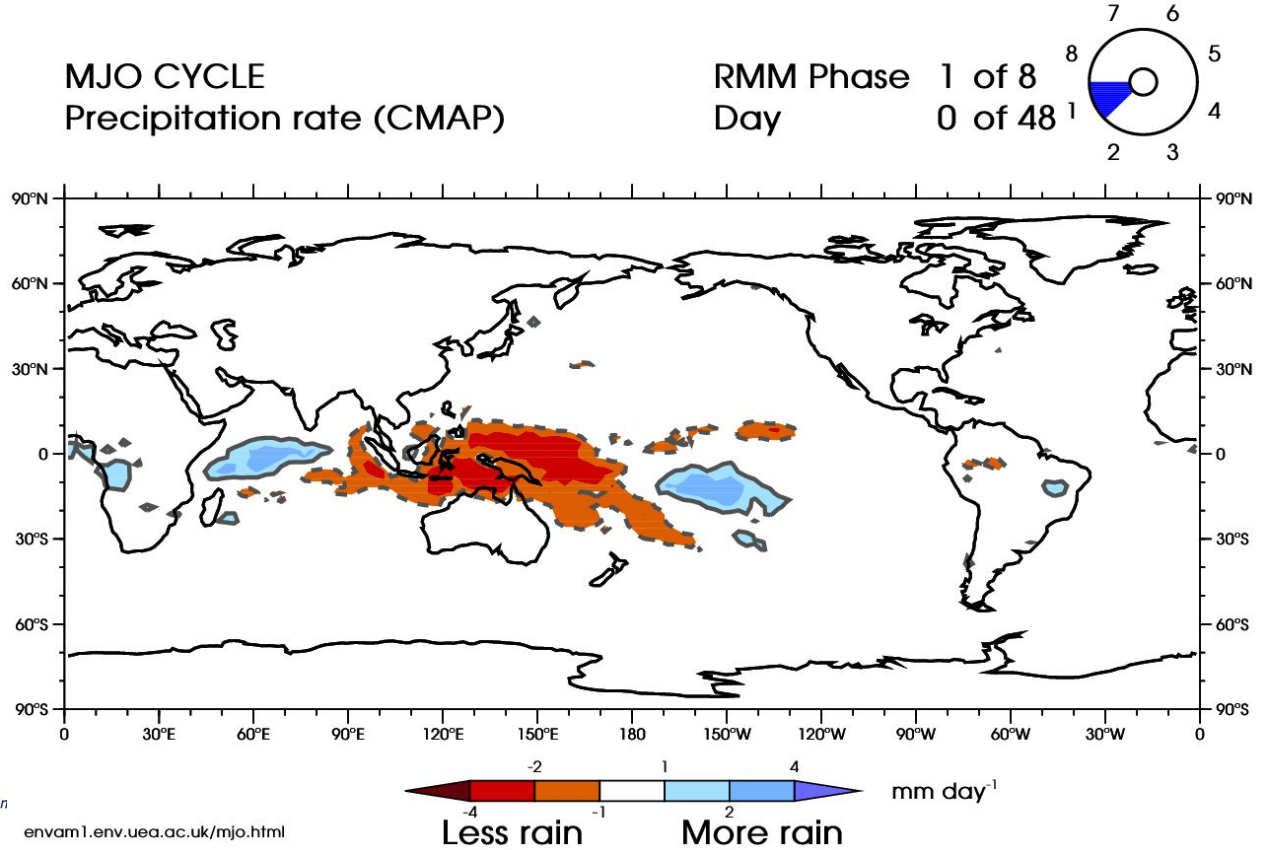
# The Madden-Julian Oscillation is the main source of sub-seasonal variability in the tropics

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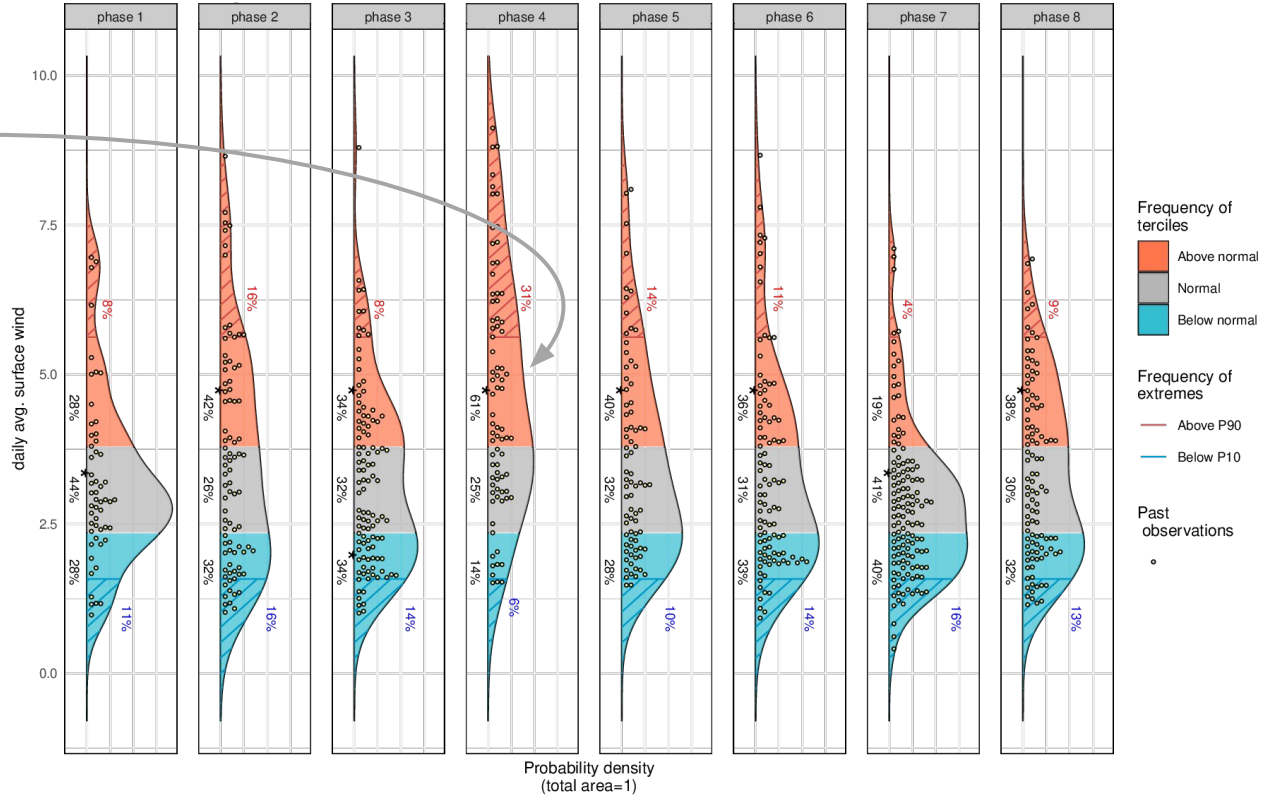
# Strong MJO events modify the distribution of wind speeds in Europe

In Frankfurt, during strong MJO events in the phase 4 there are double probabilities of observing above normal daily mean wind speeds, and triple probabilities of observing above P90 winds

- Wind speed: ERA5
- MJO index: BoM
- Period: JFM 1998-2017

Climatological wind distribution in Frankfurt during strong MJO events

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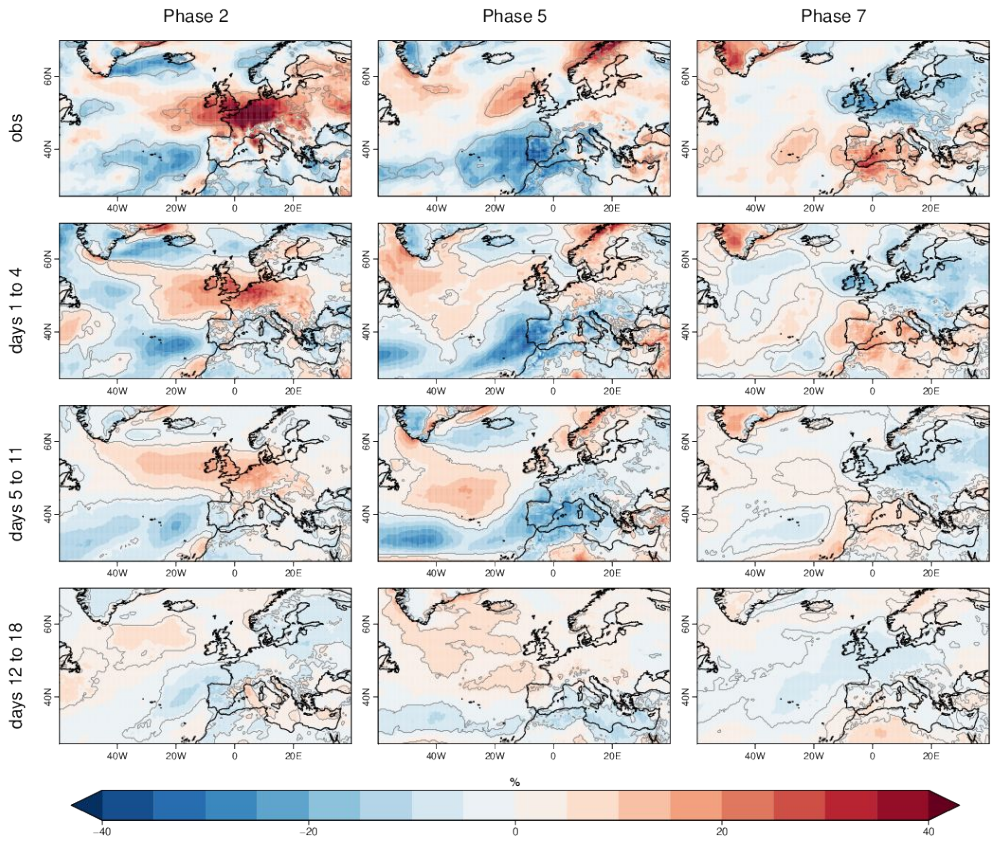
# ECMWF sub-seasonal forecasts do not reproduce the expected teleconnective impacts of the MJO on surface wind

Surface wind composites

ERA5 wind during strong MJO events

MFS wind when a strong MJO is forecasted




➤ Wind speed: ERA5 & MFS ➤ MJO index: S2S project ➤ Period: JFM 1998-2017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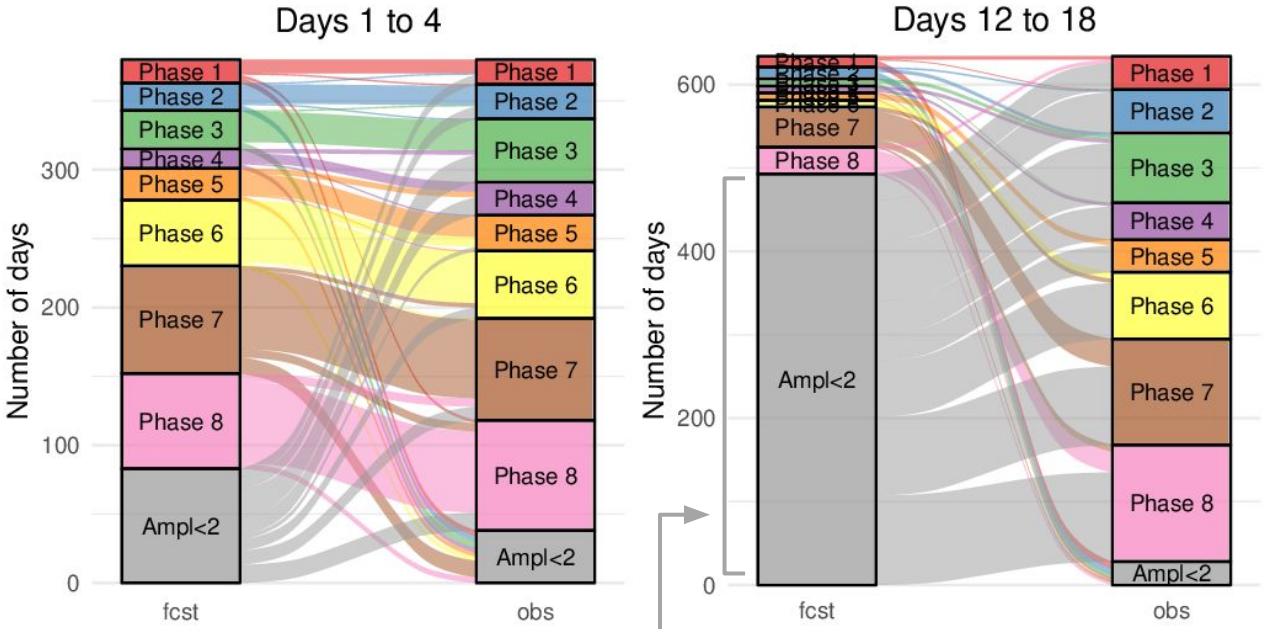
# The conditional climatology method allows to replace defective/weak teleconnection effects in the forecasts

## Conditional climatology

Employ the wind speed stratifications as a forecast of tercile probabilities whenever an MJO forecast indicates a strong event

$$\mathrm{clim}|_{\mathrm{MJO}}(d) = \begin{cases} \mathrm{clim}(x) & \text{if} \quad \widehat{\mathrm{MJO}}_{\mathrm{ampl}}(d) < 2 \\ \mathrm{clim}(x|\mathrm{MJO}_{\mathrm{ph}}(x) = 1 \quad \text{and} \quad \mathrm{MJO}_{\mathrm{ampl}}(x) \geq 2) & \text{if} \quad \widehat{\mathrm{MJO}}_{\mathrm{ph}}(d) = 1 \quad \text{and} \quad \widehat{\mathrm{MJO}}_{\mathrm{ampl}}(d) \geq 2 \\ \vdots & \\ \mathrm{clim}(x|\mathrm{MJO}_{\mathrm{ph}}(x) = 8 \quad \text{and} \quad \mathrm{MJO}_{\mathrm{ampl}}(x) \geq 2) & \text{if} \quad \widehat{\mathrm{MJO}}_{\mathrm{ph}}(d) = 8 \quad \text{and} \quad \widehat{\mathrm{MJO}}_{\mathrm{ampl}}(d) \geq 2 \end{cases}$$

# Forecasts of strong MJO events are inaccurate more than 10 days ahead




- MJO fcsts: MFS (S2S index)
- MJO obs: ERA-I (S2S index)
- Period: JFM 1998-2017

Huge portion of missed events in week 2

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# Seasonal fcsts derived from four Euro-Atlantic teleconnections


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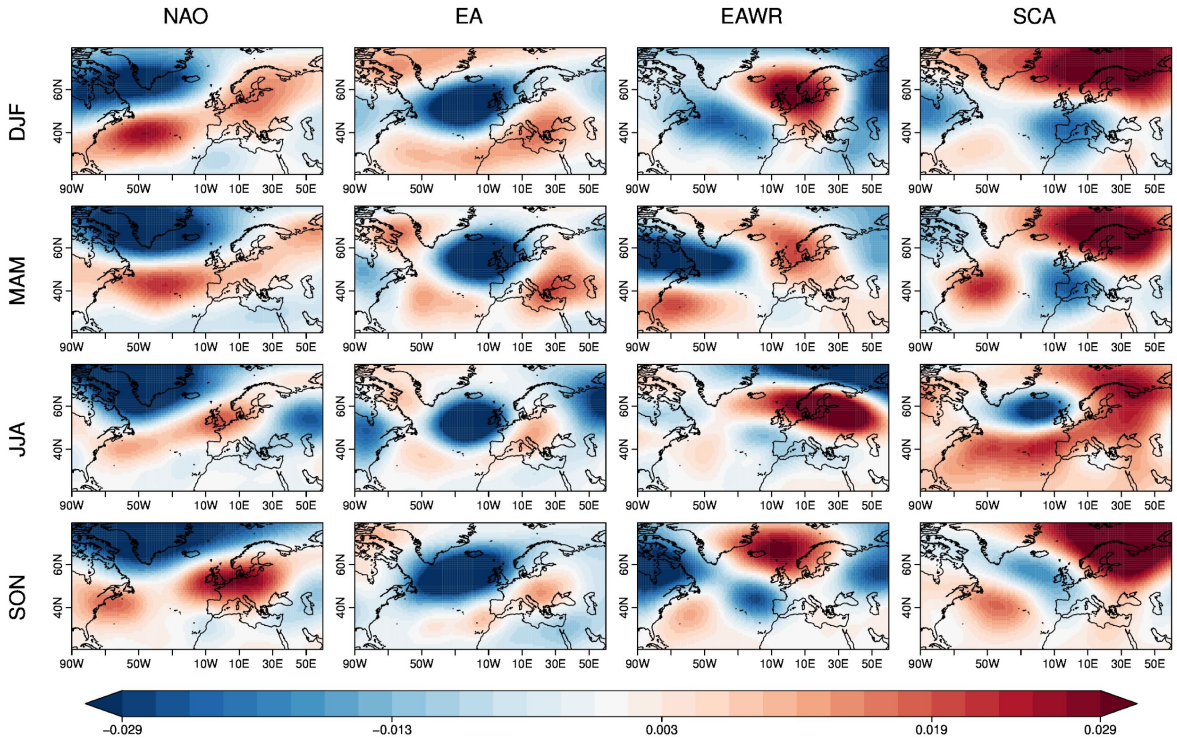
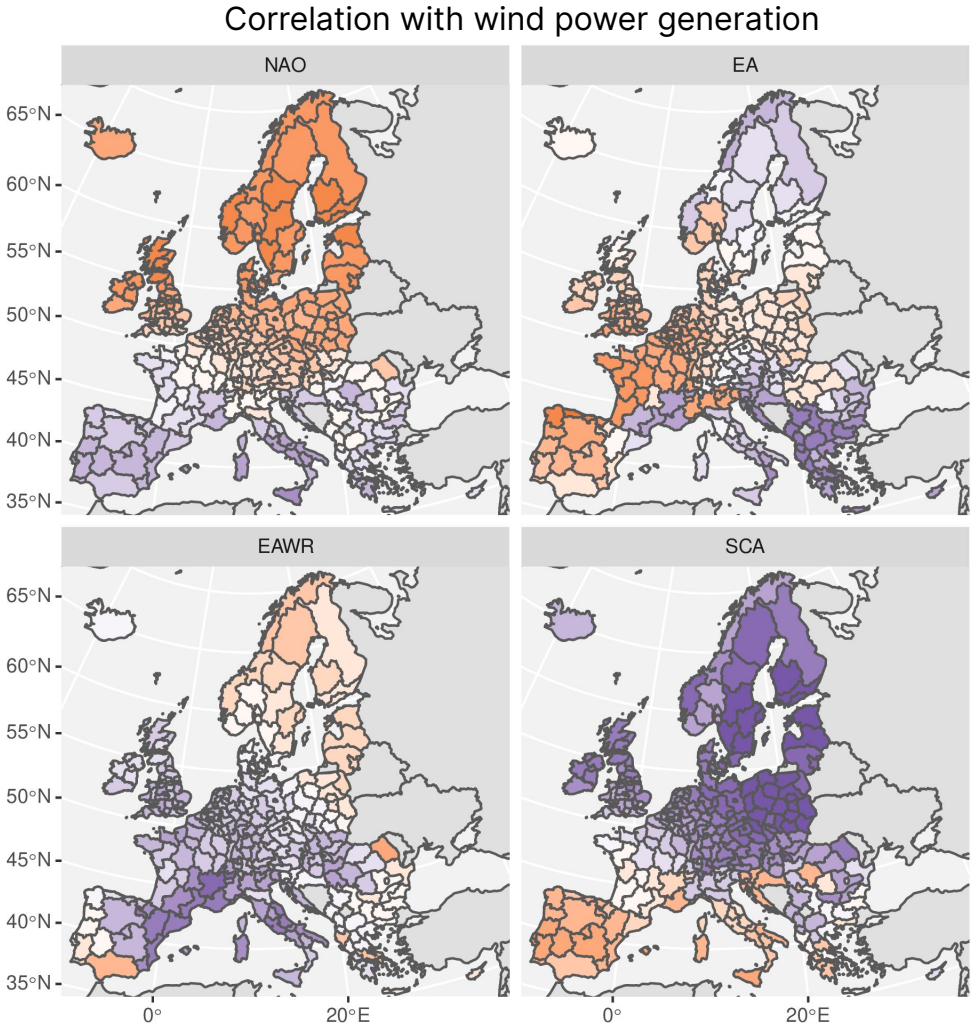
# Euro-Atlantic Teleconnections: a summary of the atmospheric circulation

- **Variable**
  Seasonal anomalies of 500 hPa GH
- **Source** ERA5
- **Period** 1981-2018
- **Region** 90W-60E & 20N-80N
- **Method** Rotated
  EOF with varimax rotation, retaining 4 EOF modes.



# The state of the four EATCs affects wind power generation in different parts of Europe




Source: Lledó et al. in prep.

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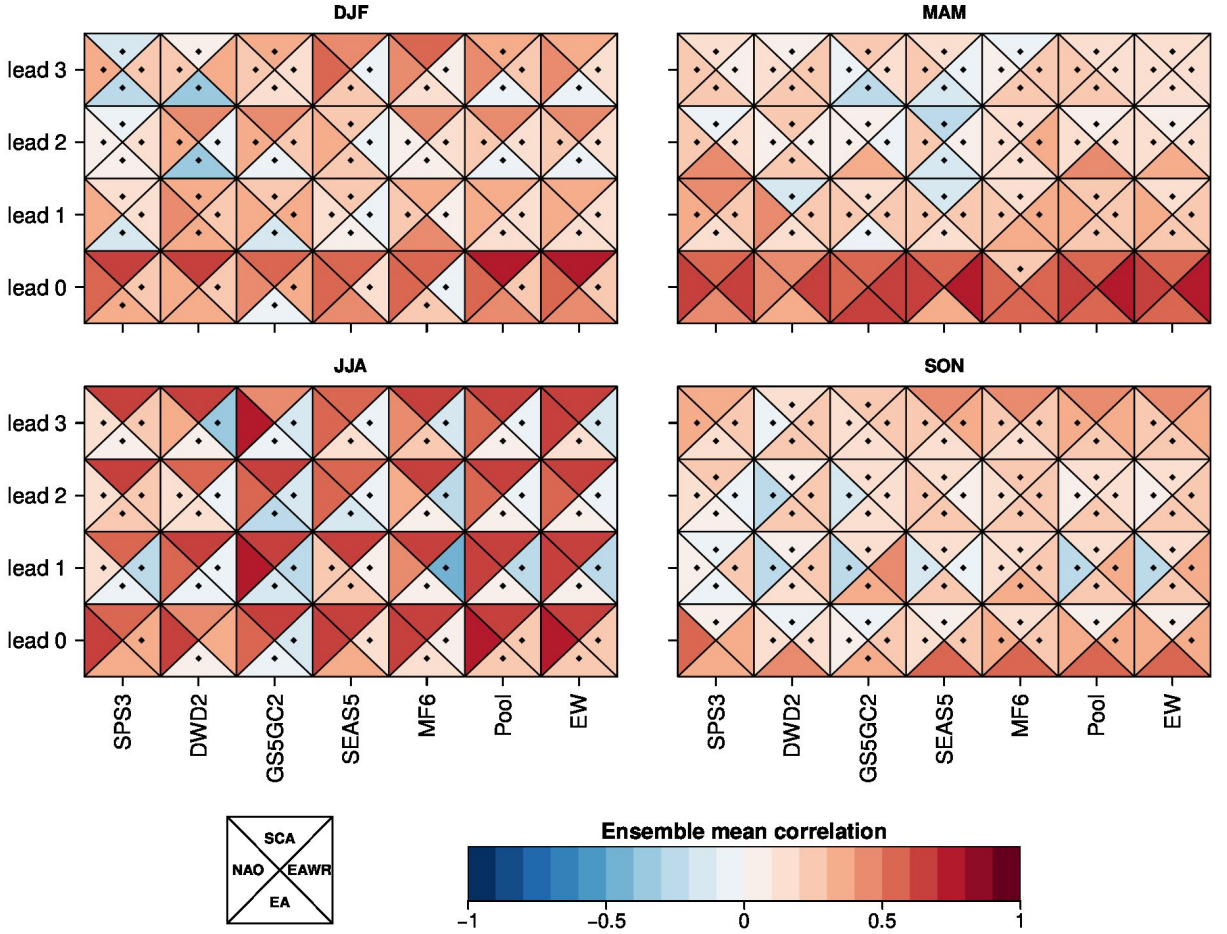
# Some of the EATCs can be predicted up to four months ahead by most dynamical systems





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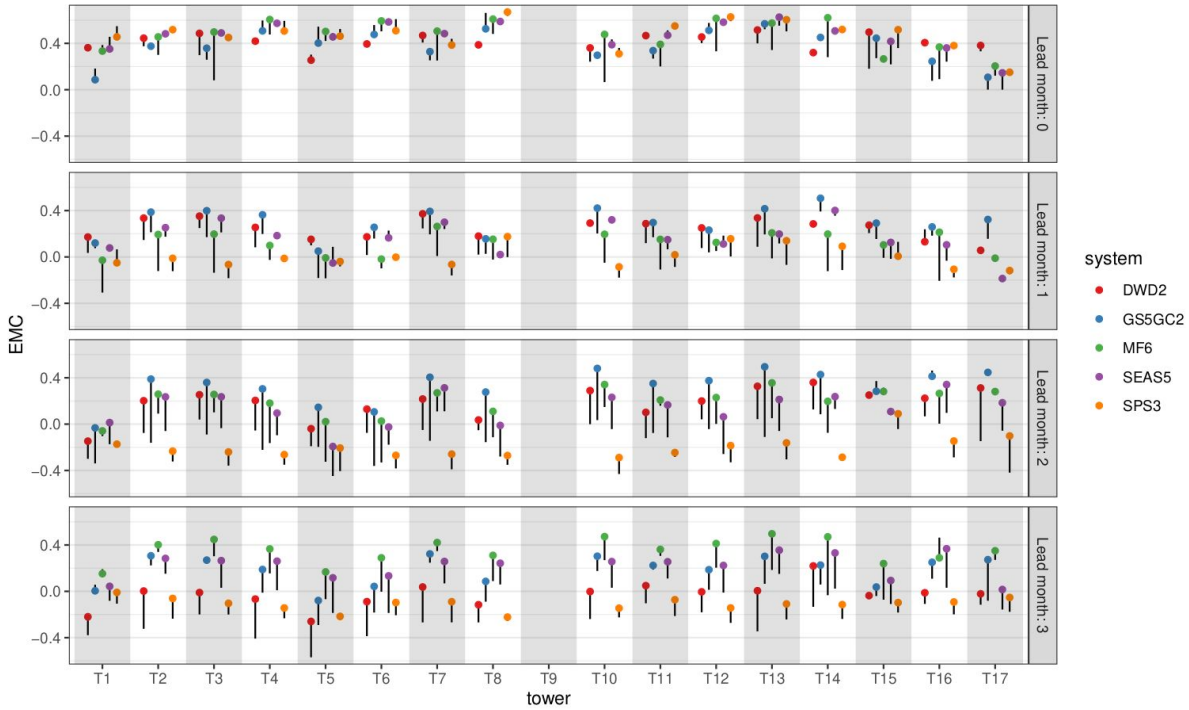
# Successful results at several locations in Europe

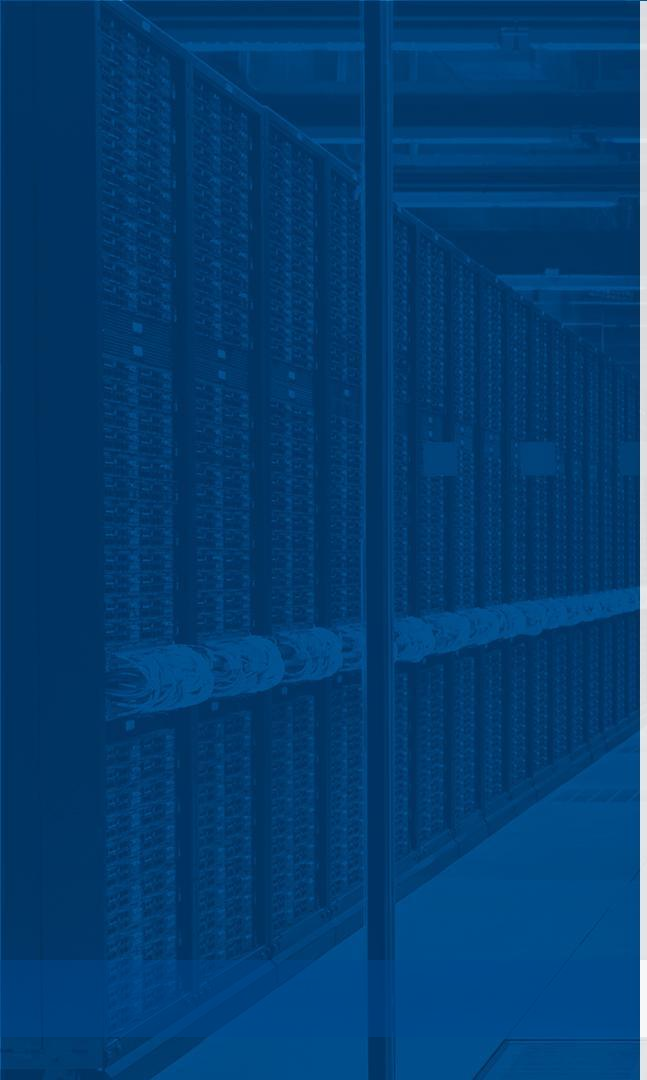


# Summary

- Earth system models can be used to produce sub-seasonal and seasonal forecasts of wind speed
- Hybrid prediction techniques can enhance the skill levels by employing teleconnection indices as intermediate variables

Lledó, L., & Doblas-Reyes, F. J. (2020). **Predicting Daily Mean Wind Speed in Europe Weeks ahead from MJO Status.** Monthly Weather Review, 148(8), 3413–3426. https://doi.org/10.1175/mwr-d-19-0328.1

Lledó et al. (2020). **Seasonal prediction of Euro-Atlantic teleconnections from multiple systems.** Environmental Research Letters, 15(7), 074009. https://doi.org/10.1088/1748-9326/ab87d2



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# Thanks for watching!

Get in touch: llledo@bsc.es